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Handbook of Sealants for Ammunition

R W Bryant

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Handbook of Sealants for Ammunition

by

R W Bryant

SUMMARY

The many factors influencing the choice of suitable
sealing methods for ammunition and allied stores
are summarised. The importance of adequate water-
proofing is emphasised, in view of the widely
varying atmospheric and other conditions to which
stores in Service are liable to be subjected.

The properties required in sealing compositions
are outlined and performance specifications for
lutings and cements are proposed. Details of
selected lutings and cements are given on
individual data sheets.

The types of joint normally used are considered,
and the methods of applying sealing compositions
to them are discussed.

A bibliography with abstracts of 24 references is
included.

CONTENTS

ILLUSTRATIONS

1   INTRODUCTION

The subject of the waterproofing of ammunition has attracted increased attention in recent years. It has been found that many kinds of ammunition can be rendered useless or even dangerous by ingress of moisture under bad storage conditions; the need for efficient sealing materials and methods is obvious.

A decisive step towards rationalising Service sealing compositions was taken in 1956, when a Manual of Sealing compositions for Ammunition was published,[1] which incorporated information supplied by designers.[2] Five amendments to the Manual were issued at intervals up to 1961, when the pressure of other work became too great for its further continuance. A total of 270 copies have been printed and issued, which confirms the need for such information to be widely disseminated, but it is now out of print, in addition to being out of date.

Since the issue of the Manual, investigations have continued into various aspects of the sealing of joints, and the results of these investigations have been incorporated into this Handbook, which is intended to be an up to date guide to the selection of preferred sealing materials for any of the various types of joint found in ammunition.

The factors which influence the choice of sealing method are described in Section 2, while Section 3 deals with sealing compositions of current import-ance, including the most useful of the compositions developed and tested in this Establishment. Data sheets for selected cements and lutings are provided in Section 4, and these are indexed (Appendix C). There are other types of sealing

material which are not dealt with in detail. Thus protective coatings and adhesives (seldom used as sealants), rubber O-rings and rubber and plastic washers are excluded.

The situation is continually changing, new compositions being developed and others perhaps becoming unobtainable. In an endeavour to widen the choice of lutings and cements, performance specifications are proposed, laying down criteria against which future sealants may be judged. These specifications are put forward in Appendices A and B, for lutings and cements respectively.

A bibliography with abstracts (in chronological order) is given in Section 6, to enable direct reference to detailed reports and findings. Requests for copies of these reports should be addressed to D/ERDE in the first instance.

Finally, it is hoped that this Handbook, in presenting some of the many factors which must influence the choice of a sealing method suitable for any particular joint, will be of assistance to designers and users. It is emphasised that the Handbook can never be exhaustive nor entirely up to date, and that all users wishing to employ any sealant should seek the latest advice, giving all information relevant to the proposed application.

2   FACTORS CONTROLLING CHOICE OF SEALING METHOD

2 1   Design Considerations

2 1 1   General

Despite a long history of ammunition designs which can only be sealed with difficulty, it remains the fact that many explosives stores are designed primarily to satisfy functioning requirements,

insufficient consideration being given to sealing as an essential element in the design. A frequent result of this approach is a botched-up seal, in which both mechanical seals (washers etc) and sealing compounds are employed. In a well designed joint, one or the other should be sufficient.

2 1 2   Packaging

The waterproofing of any store cannot be fully considered without reference to its package. The ideal is to pack a fully waterproofed store, which may itself consist of an assembly of separately waterproofed components, inside a waterproof package. In emergency it may be necessary to issue incompletely waterproofed stores in waterproof packages, but this is to be deprecated. The user should always be made aware of limitations of this sort. Fully waterproofed stores are sometimes acceptable in non-watertight packages, but care should be taken that the package does not actually promote undesirable effects by entrapping moisture.

Supporting materials enclosed within packages, for example expanded rubbers, plastics, rubberised hair, wood etc, may produce vapours having extremely damaging effects. Protection against these vapours is often essential.

2 1 3   Types of Leak

The following types of leak may occur:

a   Leakage of water (or other liquids) under
        pressure, usually in one direction only,
        through relatively large holes.

b   Diffusion of water vapour through narrow
        channels; this may result in the special
        case of c below.

3

c   Breathing - the entry of small quantities of
    moist air through narrow channels over long
    periods. This process operates alternately
    in opposite directions, and is caused by
    changes of atmospheric temperature and pressure.
    If the diurnal temperature fluctuation is large,
    liquid water may condense in the store.

d   Permeation of gas, especially water vapour,
    through materials. This process differs from b
    above in that the permeating gas dissolves in
    the external surface of the material, and is
    regenerated in due course from the internal surface.

The first three conditions can be avoided by proper
joint design and the use of suitable sealants. However,
permeation through a plastic film can never be wholly
prevented, but may be reduced by coating with a
relatively impermeable varnish film. The rate of
permeation is directly proportional to the area, and
inversely proportional to the thickness of the plastic.

Choice of a suitable sealing composition will also
depend on the atmospheric and other conditions likely
to be encountered, and on the type of joint under
consideration.

2 2 Atmospheric and Other Conditions Likely to be Encountered

A store will probably be required to remain service-able in a wide variety of climatic conditions, ranging from arctic to tropical, at high altitudes in aircraft (either during transport or use), during sea transport and in landing operations (including total immersion). The combination of such factors, if the store is insufficiently sealed and protected, may well render it unserviceable, and possibly unsafe. Some effects of the various conditions are summarised below.

2 2 1 Temperate Climates

The most important characteristic of temperate climates is maintained high humidity, which occurs in spring, autumn and during mild winters. Rain will find its way through an imperfectly sealed joint if exposure is prolonged. Water vapour will gain ingress through channels so narrow that they are impervious to liquid water, and this is accentuated by breathing, as described above (Section 2 1 3). Water vapour will also slowly permeate through plastics.

In every case, moisture is liable to condense on cool internal surfaces and to be retained by hygroscopic explosives and packaging materials. It may result in undesirable chemical reactions such as the formation of dangerously sensitive explosives, or it may support microbiological growth (causing, for example, the rotting of textiles). Further, the failure of electrical circuits may be caused, and indicating or optical instruments may be rendered useless through the formation of a misty film on transparent surfaces.

2 2 2 Tropical Climates

The adverse effects of temperate climates will all

be intensified under tropical conditions. Continued high humidity will be more destructive owing to higher ambient temperatures. The amount of breathing through narrow channels will be increased by large diurnal temperature fluctuations, and permeation is increased both by temperature and by the increase in the quantity of water in the atmosphere.

Tropical climates especially encourage the growth of insects, bacteria and fungi, the attacks by any or all of which on improperly sealed ammunition may render it useless.

Some sealing compositions under maintained high temperatures will be physically or chemically unstable. For example, cements or lutings may soften or even melt, or may react with either the materials of the joint, or atmospheric oxygen, and become hard and brittle.

2 2 3 Desert Climates

Desert regions are characterised by low relative humidities (with a diurnal variation of say 5 to 25 per cent r.h. in the driest season) and high day temperatures (up to 60°C in the shade) falling to -10°C at night in extreme cases. Direct exposure to the sun will give surface temperatures appreciably higher than 60°C. The normal diurnal temperature change is about 40°C and is sufficient to cause considerable expansion and contraction and possibly warping of components. The low relative humidity and high temperatures will cause moisture-containing materials such as wood, textiles and paper to dry out, showing progressive change in size. In addition the sun's direct rays (especially the ultra-violet) may cause rapid chemical deterioration of rubbers, plastics, organic coatings and similar materials.

Dust and sand particles can have an abrasive effect if wind-blown on to exposed sealing compositions

(especially varnishes) and may result in their removal.
Dust particles are often hygroscopic and after
penetrating very small openings may then cause
deterioration due to their absorption of moisture.

2 2 4   Arctic Conditions

The main characteristics of arctic regions are very
low temperatures (down to an extreme of about -70°C)
and high winds. Although the humidity is low at
these temperatures, there may be a high proportion
of minute particles of ice. These can penetrate
small apertures to the extent of completely filling
enclosed spaces, and on thawing cause serious
deterioration.

Low temperatures may cause embrittlement of sealing
compositions and possibly their fracture due to
differential contraction of the materials joined.

2 2 5   High Altitudes

The increasing speed and altitudes being attained
by aircraft give rise to special problems since
most stores may be transported by air. At an
altitude of 60 000 ft (18 000 m) the atmospheric
temperature is about -90°C but at supersonic
speeds the outside surface of the aircraft may be
heated considerably.

The atmospheric pressure at 60 000 ft (18 000 m)
is about 1 psi (0.07 bar) which imposes a large
pressure differential on a joint and may result in
a serious leak, especially if the sealing compound
is adversely affected by the low ambient tempera-
ture. Such a leak would breathe if the atmospheric
pressure varied subsequently.

2 3   Sealing Compositions

Sealing compositions may conveniently be considered under two headings (a) weak (or temporary) and (b) strong (or permanent) sealants. Weak sealants are used when the sealed joint may need to be broken and remade; they do not contribute significantly to the strength of the joint. Examples are washers or O-rings, PTFE tapes, and lutings, which have the consistency of a stiff grease. Permanent sealants, sometimes called cements, are applied to the joint in liquid form and subsequently harden in situ to give joints which are likely to be difficult to undo. However, the mechanical strength of sealing compositions is generally less than that of the constructional materials with which they are used. They should therefore not be called upon to perform more than their legitimate function of sealing gaps between components, which should be fixed to each other by conventional mechanical means (screwing, rivetting, swaging, etc). Grub-screws should be avoided if possible as they may provide a by-pass route for water vapour. If a grub-screw has to be used, both threads should be coated with sealing composition before assembly. An alternative method of sealing is to solder a metal disc into a recess above the top of the grub-screw.

There have been instances where the designer has needed to use cements or adhesives of greater strength than usual for special purposes. Great care should be exercised in selecting compositions of this kind as there are usually explosives compatibility difficulties. For this reason, such materials have been excluded from this Handbook, and it is recommended that requirements to use them in ammunition be referred to the Compatibility Section at this Establishment.

Service sealing compositions are mainly used to seal parallel-threaded joints. They have, to date, been developed in this laboratory, because there are

special requirements more stringent than are normally stipulated in commerce. However, commercial sealants have recently improved in performance, and have been examined in threaded joints. Both temporary sealants (lutings and PTFE tapes and cords) and permanent or setting cements have been assessed and the work summarised.[24] It is discussed below.

2 3 1   Temporary Sealants

PTFE tapes and cord are relatively inefficient in parallel-threaded joints.[22]

One commercial luting (Hylomar SQ 32/S:see Data Sheet No 3) has been found[23] to be comparable as a sealant with the Service materials (Lutings Mk 8 and Mk 9: see Data Sheet No 2), but has inferior low temperature performance, heat stability and water resistance. No temporary sealant tested withstood thermal cycling in heterometallic joints.[22]

These investigations led to statements[19,23,24] of the requirements of a luting. These are that a luting:

    i   should not slump under its own weight at the highest working temperature,

    ii   should not be hard and brittle at the lowest working temperature,

    iii   should remain extensible during application and use,

    iv   should be tacky and adherent to metallic and other surfaces,

    v   should be water resistant and have a low water vapour permeability, and

    vi   should be physically stable and chemically unreactive.

It seems undesirable to restrict the future development of lutings to this laboratory. A performance specification based on the above requirements and on existing specifications, has therefore been drafted (Appendix A). In this, clauses 4 and 6 control slump and consistency at elevated temperature (requirement i); clause 5 controls consistency at low temperatures (requirement ii); clause 7 controls extensibility (requirement iii). Requirement iv is difficult to quantify and is covered in the description (clause 2). To cover water resistance, clause 9 has been drafted, based on work in this laboratory. Water vapour permeability is difficult to measure, although it has been done,[3] and it has been decided to rely on clause 9 to exercise some control of this aspect. The presence of inorganic fillers may lower water resistance, hence the control of ash content (clause 11). Requirement vi is covered by clauses 8 and 10, and indirectly by clause 3 for compatibility with explosives, for which freedom from lead is also a requirement (clause 12).

The design of joints using sealing washers and O-rings has not been investigated here, but grades of rubber and plastic which are compatible with explosives will be recommended on application to this Establishment. The development of washers, O-rings etc is mainly by commercial firms. The British Hydromechanics Research Association carries out research into dynamic seals and is a valuable source of information on mechanical seals in general. The use of such seals in fuzes has been studied.[16]

If a sealant is used in conjunction with a washer, it is advisable to apply it to both sides of the washer before assembly. All joints must be screwed home as firmly as possible without displacing the washer.

2 3 2 Permanent or Setting Cements

Twenty four commercial cements, including polysulphides, polyurethanes, epoxides, silicones, surface-catalysed

compositions and compounds hardened by atmospheric moisture, have been tested here as thread sealants.[24] Several were superior to the Service material (RD 1286) in a stringent thermal-cycling trial. The experience gained permits a statement of the requirements for a general purpose waterproofing cement. These are that the freshly mixed cement should:

   i   have a viscosity of not less than 1 N s/m^2 (10 poise) and not more than 250 N s/m^2 (2500 poise),

  ii   have a pot-life not less than 1 hour,

 iii   have a maximum setting time of 24 hours, and

  iv   have a contraction not more than 4 per cent by volume while setting.

The set cement should:

   v   be flexible over a wide temperature range and should not flow at high temperatures,

  vi   be physically stable and chemically unreactive, and

 vii   have a cohesive strength, and adhesive shear strength with all the adherends, not less than one-third its rigidity (shear) modulus.

Again, it seems undesirable to restrict the future development of cements to this laboratory. A performance specification based on these requirements has therefore been drafted (Appendix B). In this, clause 3 controls the initial viscosity and pot-life, requirements i and ii. The upper limit of 250 N s/m^2 represents the maximum viscosity for convenient application. Clause 4 controls the

setting time, requirement iii . The contraction
on setting (clause 5, requirement iv) is conveni-
ently followed by measuring the change in density
with time. Requirement v is covered by clauses 7
(resistance to flow at elevated temperature) and 10
and 12 (by implication - a rigid cement will not comply
with these clauses). Requirement vi is covered by
clause 6 and by the requirement for compatibility
with explosives. Requirement vii (clause 12) arises
from the investigation into the maintenance of seals
between heterometallic assemblies during thermal
cycling,[24] as discussed in Section 2 5 1 below. The
implicit requirement for water resistance is met by
clause 11.

2 4 Application of Sealing Compositions

2 4 1 General

Many metallic components of stores when manufactured are treated with temporary protectives such as lanoline or grease. Before applying sealant, it is important that they should be thoroughly degreased, since the temporary protective will prevent adequate adhesion of the sealant and may also cause it to deteriorate. Vapour phase degreasing is strongly recommended. The process of degreasing with a solvented rag may sometimes be unavoidable, but this method necessitates regular change of solvent bath and rags, ideally on a counter-current principle, in which a number of solvent containers (each with its rags) are used in sequence, the first (and presumably dirtiest) being discarded at intervals and a clean bath and rags added at the end of the line. The solvent must be removed from the surfaces to be bonded before applying sealant.

Sufficient sealant should be applied for the excess to be extruded all round the joint (the "witness"), which may then be removed by means of a rag damped (not wet) with suitable solvent. Cements must then be allowed a period to set before handling the store.

Difficulty may be experienced in sealing a store in which a threaded plug is finally assembled, if this action considerably compresses the contained air (as is sometimes the case in the assembly of fuzes into filled shell and of magazine into fuzes). In such cases consideration should be given to the provision of a shoulder and a suitable rubber or plastic sealing washer.

Normally visual inspection of an assembled store will be insufficient to determine whether a seal is

perfect. It is recommended that an agreed propor-
tion of the assemblies be subjected to a simple leak
test, by the application of a vacuum or air pressure
at a differential pressure of about 5 psi (0.3 bar).
Such a test need be neither lengthy nor laborious,
and has the advantage of promoting efficient sealing
techniques in the filling factory.

2 4 2   Application of Lutings

Luting Mk 9 may not be applied molten, because its
desirable properties depend critically on the rate
of cooling when solidifying. Neither is it suitable
for thinning with any solvent. It may be warmed
uniformly to about 60°C if this will facilitate
application; pressure guns may also be used. The
commercial luting Hylomar SQ 32/S, which is
unfortunately not generally suitable for Service
ammunition applications,[23] is obtainable diluted
with solvent, so that it may be applied with a brush.
The solvent should be allowed to evaporate before
making a joint, however, otherwise a porous joint
may result as the solvent escapes.

2 4 3   Application of Cements

Cements setting by loss of solvent are not recommended.[6]
Chemically setting cements should be used in the
manner recommended by the supplier. Many of these
compositions are too viscous to apply by brush,but a
spatula or palette-knife may be used. Alternatively
apparatus is now commercially available for continu-
ously metering and mixing two-component cements, and
the mixed cement may be fed into a suitable applicator.

One part cements, which set without adding catalyst,
are now coming into use. Examples are Loctites,
which set to rigid solids, and room temperature vulcan-
ising (RTV) silicone rubbers in which the curing
reaction is initiated by the water vapour in the air.
The one part cements have obvious attractions for

14

automated assembly lines; a potential dis-
advantage of Loctites is that they may find their
way into the store and lock the mechanism of, for
example, a fuze.

2 5   Types of Joint

The majority of joints in ammunition are threaded, but
turned-over and swaged, and sleeve joints also occur.
These joints are discussed in turn below. Unless
otherwise stated, metal/metal joints are intended.
Joints in plastics are considered separately (Section
2 5 4).

2 5 1   Threaded Joints

The role of sealants in sealing threaded joints, which
form the majority of ammunition closures, is now well
defined. The practical experience that joints made
with solvented compositions do not remain sealed has
been confirmed by systematic experiment.[6] The
relative contribution of sealing compositions and
joint design to the sealing of threaded joints have
been assessed.[8,11]

When components having the same coefficient of thermal
expansion are considered,[8] the most important single
factor in the sealing of threaded joints is the
quality of the sealing composition. The next most
important factor is the combination of joint design
with mode of application of the sealing composition,
as shown in Fig 1, page 17. Application to both
threads is preferable, if it is permissible to force
composition into the assembly. It is also preferable
to apply the sealant to the whole of the threads, so
that a complete ring of material is extruded when the
joint is closed. If less composition is used, it is
then preferable to apply it completely round the
periphery of fewer threads, rather than in a series
of dabs. Sealing is also improved by screwing on to
either (a) an external shoulder if composition is
applied to the male threads, or (b) an internal shoulder
if composition is applied to the female threads. A
joint not screwed on to a shoulder is relatively
difficult to seal. Normally, factors such as the metal

16
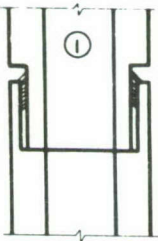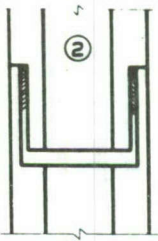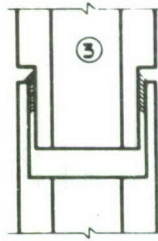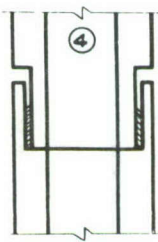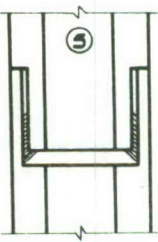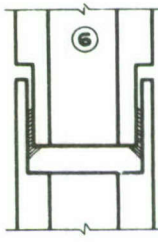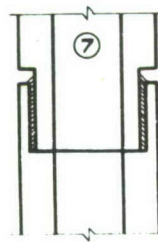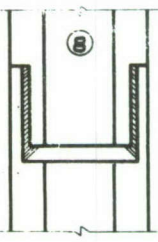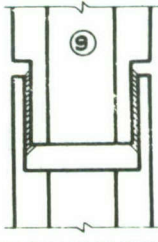
JOINT CEMENT	SCREWED ON TO INTERNAL SHOULDER	SCREWED ON TO EXTERNAL SHOULDER	SCREWED ON TO NEITHER SHOULDER
APPLIED TO MALE THREADS BEFORE ASSEMBLY	①	② GOOD SEAL	③ SIMILAR TO COMBINATION ① THIS IS THE COMBINATION MOST DIFFICULT TO SEAL
APPLIED TO FEMALE THREADS BEFORE ASSEMBLY	④ SIMILAR TO COMBINATION ② GOOD SEAL	⑤	⑥ SIMILAR TO COMBINATION ③
APPLIED TO BOTH THREADS BEFORE ASSEMBLY	⑦ THIS IS THE COMBINATION MOST EASILY SEALED	⑧ SIMILAR TO COMBINATION ⑦	⑨ SIMILAR TO COMBINATION ⑦ BUT WITH NO SHOULDER SUPPORT

FIG.1 **THE COMBINATIONS OF THREADED JOINT DESIGN WITH METHODS OF APPLYING SEALING COMPOSITION.** The final position of sealing composition after assembly is indicated.

17

used, the dimensions of the joint, and even
incorrect application of the sealing composition, are
individually of minor importance, although the metal
of which the joint is made may affect the quality of
sealing when surface-catalysed compositions (eg
Loctites) are used.[15]

The effect of mechanical stresses caused either by
cyclic changes of temperature, or by impact, on the
sealing of various threaded joints has been deter-
mined.[11] Thermal cycling does not affect the
sealing of joints unless the components are made
of dissimilar metals (heterometallic joints). The
most important single factor in the resistance of
such joints to thermal cycling is the joint design
(external, internal, or no shoulder), coupled with
mode of application of sealing composition. The
next most important factor is the quality of the
sealing composition. There is no significant
difference between the performance of joints
made of different bimetallic combinations of
aluminium, brass, and steel. A single axial
impact caused by dropping steel threaded assemblies
"end-on" through 4 ft 6 in (1.37 m) on to concrete
has little effect on the sealing,[11] but the
strength may be more seriously affected.[10]

Theoretical analysis[24] of the strain imposed on the
sealant by thermally cycling heterometallic joints
has led to an understanding of the necessary magni-
tudes of the adhesive and cohesive strength and the
flexibility of a sealing cement. These properties
can now be specified as a function of the materials
and dimensions of the joint and of the temperature
range to be withstood. As shown by the data in
Figure 2, page 21, for heterometallic joints of
appreciable size [say more than 1 in (25 mm)
diameter] the analysis indicates the need to use
a rubbery (and necessarily relatively weak)
cement if the joint is to remain sealed when
thermally cycled over a long period.

The failing torques of joints made with various sealants have been assessed. The failing torque of a cemented threaded joint is the sum of the tightening torque and the contribution of the cement.[10] When the latter is converted into a shear strength, this is found to be equal to the shear strength of a planar joint of the same materials provided the cement layer is of equivalent thickness.[20]

FIG.2 CEMENTS FOR SEALING THREADED JOINTS OF DISSIMILAR METALS
WHEN THERMALLY - CYCLED.

21

RIGID LOCTITE

Diagonals represent, as a function
of the Rigidity Modulus, the
minimum joint strength necessary
to sustain the radial strain
imposed on threaded joints
between dissimilar metals by
the indicated change in temperature.
Any point to the right of a diagonal
shows a cement which will not
satisfactorily resist the indicated
thermal cycling in BSW joints of
medium fit. Both soft gels and
rigid plastics are insufficiently
strong despite the large difference
in rigidity modulus. The intermediate
rubbers are the most satisfactory,
provided they have adequate
adhesion. RD 1286 is initially
satisfactory, but fails eventually
as it stiffens due to continued
curing.

PLASTIC LOCTITES

RD 1241B
MAGNESIUM OLEATE CEMENTS
RD 1248

COHESIVE STRENGTHS OF:
NATURAL RUBBER COMPOSITIONS
GRS RUBBERS

RD 1286 CURING

SILASTOSEAL E
TS 479
SILASTOMER 9161

SILICONES HAVING POOR ADHESION

JOINT SIZE: L=2 D=
TEMPERATURE CHANGE °C

(SOFT GELS) (SOFT RUBBERS) (STIFF RUBBERS) (SOFT PLASTICS) (RIGID PLASTICS)

RIGIDITY MODULUS, BARS

JOINT STRENGTH, BARS

2 5 2   Turned-over and Swaged Joints

Most joints of this kind are now sealed by turning
over on to a previously dried layer of rubber latex
composition. Liquid chemically setting cements
(eg RD 1286) which are rubbery when set usually
seal satisfactorily, but tend to contaminate tools.
Bituminous compositions (eg RD 1219) preceded
 ·bber latices for such joints.

2 5   Sleeve Joints

Sleeve ͟ ᐟnts are generally the most difficult to
waterproo͟ ᐯrobably mainly because of the diffi-
culty of fi͟ ᐥq the parts relative to one another.
Solvent-free ͟ ᐟents may be satisfactory; mechani-
cal joints (eg ͟ ᐟeluring into a groove containing
a rubber washer) ᵼ. ᐤ been successfully used.
Differential therma͟ ᐭpansion of the two components
needs to be considereᗉ ᐭee above), and is likely to
dictate the use of a ruᒐ ᐭy sealant in hetero-
metallic joints.

2 5 4   Cementing of Plastics

Most of the preceding sections are   ᐪevant to the
sealing of plastics/plastics and plaᒐ ᐤs/metal
joints but some special considerations   ᐭly to
the cementing of plastics components; fᴄr example,
bonding may be hindered by the presence of mould
release agents.

Plastics may be divided for convenience into two
classes: (a) readily soluble and (b) insoluble
or soluble with difficulty. Class (a) includes
for example cellulose acetate and nitrate (celluloid),
polystyrene, polymethylmethacrylate, polycarbonate
and polyphenylene oxide: class (b), polythene, PTFE,
phenolic mouldings, Melinex and Delrin.

The soluble plastics may be cemented together by a
solvent if the surfaces to be joined are smooth and
close-fitting. For gap joints a bodied cement consi-
sting of a solution of the polymer is preferable.
The cemented parts should be held in contact while
drying to allow for contraction of the cement. The
majority of the plastics in class (b) are difficult
to bond, and each joint would have to be considered
on its merits.

Thermal cycling causes especially large strains in
joints between plastics and metals. Here again it
is difficult to generalise, and such joints should
be referred to ERDE for individual consideration.

3   CURRENT COMPOSITIONS

In this section, current compositions are classified
according to type, ie coating materials, adhesives and
cements and lutings.

3 1   Coatings

Coating compounds bearing RD numbers believed to be
currently in Service use include RD 1151B, RD 1158G,
RD 1170, RD 1176, RD 1177, various RD 1198 composi-
tions, RD 1218, RD 1219, RD 1229, RD 1246B, RD 1272,
RD 1276A, RD 1278, RD 1281, RD 1282 and RD 1283.

Particulars of these were included in the original
Manual,[1] but their use as sealants is extremely
limited. Up to date information about compatibility
with explosives is available from this Establishment,
and information about specifications from the
Inspecting Authorities.

3 2   Adhesives

Similar remarks to those in Section 3 1 above apply
to solvented adhesives. These include RD 1221A,
RD 1256, RD 1273 and RD 1279. No solvented composi-
tion is suitable for maintaining a seal in threaded
joints between metallic components.

Solvent-free, structural adhesives form a class which
does not lend itself to the data-sheet approach,
since no adhesive of this kind, setting at room
temperature and compatible with all explosives, has
yet been developed. Adhesives compatible with
certain explosives are available, but each use has
to be considered on its merits, and it is recommended
that enquiries about these materials in ammunition
be referred to the Compatibility Section at ERDE.

3 3   Cements and Lutings

The remaining category is that of cements and lutings.
Of the cements bearing RD numbers, only RD 1200A and

RD 1286 are of current importance. RD 1200A is a
glycerine-litharge composition setting to a hard
brittle solid with excellent resistance to white
phosphorus and mineral oils, but is of only limited
use. RD 1286 is a rubbery cement widely used. 24
Superior rubbery compositions from commercial sources
include Silastomer 9161 and Silastoseal E (Midland
Silicones Ltd) and Thread Sealer TS 479
(Alfred Jeffery & Co). Other commercial sealants
which may find uses in certain ammunition are surface-
catalysed compositions, eg Loctites (Sealant Grades).

Of the lutings with RD numbers, only RD 1284A and
Luting Mk 9 (RD 1287A, which superseded Luting Mk 8,
RD 1284) are in current Service use. RD 1284A is a
blue-grey stiff plastic material, and Luting Mk 9 is
green and of the consistency of a stiff grease.
Hylomar SQ 32/S is blue and similar to Luting Mk 9 in
consistency. It is the best commercial luting so far
examined.

4   DATA SHEETS

Data sheets on each preferred sealant follow in the order tabulated below. Information about compatibility with explosives will be given by the Compatibility Section of ERDE, and specification details are available from the Inspecting Authorities.

Type of Sealant	Composition	Data Sheet Number
Luting	RD 1284A (Sealing Composition, thick)	1
	Luting Mk 9 (RD 1287A)	2
	Hylomar SQ 32/S	3
Cement	RD 1200A	4
	RD 1286	5
	Silastomer 9161	6
	Thread Sealer TS 479	7
	Silastoseal E	8
	Loctite (Sealant Grades)	9

DATA SHEET NO 1

RD 1284A (SEALING COMPOSITION, THICK)

Description   A stiff blue-grey plastic material,
                similar to Plasticine in consistency, for
                the sealing of internal crevices in
                explosive stores. Also used in optical
                instruments. Recommended in OB Proc 39245
                (13 February 1959) as a replacement for
                all thick Service lutings.

Composition   Wax Special No 3   70 pts/wt

                Polyisobutylene, low m.w.   30 pts/wt

Reports   References 5, 12

Application   To facilitate handling, RD 1284A may be
and Handling   warmed before use, care being taken to
                avoid local overheating.
                On no account must it be melted before
                use or thinned with any solvent.

DATA SHEET NO 2

LUTING MK 9 (RD 1287A)

Description   A green sticky material, having the consistency of a stiff grease, for use as a general purpose "thin" luting: see OB Procs 39,245 (13 February 1959) and 39,525 (17 June 1960). Remains plastic at $-55^{\circ}C$ and does not flow at $+75^{\circ}C$.

Composition

Polyisobutylene, medium m.w.	46 pts/wt
Di-(2-ethylhexyl) sebacate	24 pts/wt
Polythene (grade 200 or 70)	30 pts/wt
Monastral Green G.S.	0.5 pt/wt

Reports   Reference 3

Application and Handling   To facilitate handling, this luting may be warmed before use, care being taken to avoid local overheating. On no account must it be melted before use or thinned with any solvent. A rag damped (not soaked) in white spirit may be used to remove excess luting from the external surfaces of ammunition.

DATA SHEET NO 3

HYLOMAR SQ 32/S

Description A blue adhesive material, less sticky
than Mk 9 luting, having the consistency
of a stiff grease. It is extremely
stiff below -10°C, and is inferior to
Luting Mk 9 in its stability to heat in
the presence of brass, its storage life
and water resistance. However, it is
superior to Luting Mk 9 in its resis-
tance to petroleum and mineral oils,
and it is more extensible. It has
another advantage over Luting Mk 9 in
that it may be thinned with solvent
and applied by brush.

It cannot be recommended as a general
replacement for Luting Mk 9 in
ammunition but may find specialised
uses.

Composition "Polyester-urethane"

Reports References 23, 24.
Hylomar literature from:

Marston Lubricants Ltd
Rock Ferry Oil Works
Birkenhead

DATA SHEET NO 4

CEMENT RD 1200A

Description A two-part glycerine-litharge cement to be mixed immediately prior to use to give a pale yellow liquid, which has a pot life of at least 90 minutes at 20°C. It sets to a hard brittle solid with excellent resistance to oils and white phosphorus. (Cement C.D. No 2 is essentially similar but may have a shorter pot life.) These cements may not be used in proximity to HEs, due to their lead content.

Composition Glycerine, Commercial 15 pts/wt

 Litharge, Yellow 50 pts/wt

DATA SHEET NO 5

CEMENT RD 1286

Description   A two-part cement, forming a dark brown
                  viscous fluid when freshly mixed, which
                  sets to a soft rubber. Its pot life is
                  about 2 hours at 20°C. It is in
                  general use throughout the Services for
                  sealing metal/metal joints except in
                  proximity to Amatol, see OB Proc 38,771,
                  8 March 1959.

Composition   Paraformaldehyde   6 pts/wt

                  Cashew nut shell polymer   100 pts/wt
                    (Cellobond H 8160)

Reports   References 4, 7, 8, 9, 11, 17, 18,
                    19, 20, 24.

Application   The ingredients must be kept well sealed
and Handling   till used. The proportions must be
                  rigidly adhered to. On no account must
                  there be any dilution with excess of
                  the liquid component or any other liquid.
                  The set cement is weakened by
                  trichlorethylene and solvent (coal tar)
                  naphtha which may be used, where other-
                  wise appropriate, to facilitate the
                  undoing of joints.

DATA SHEET NO 6

SILASTOMER 9161

Description A two-part silicone cement, forming
a white viscous fluid when freshly
mixed, which sets to a soft rubber.
Its pot life at 20°C is about 1 hour.
It is more resistant to thermal
cycling in heterometallic joints
than RD 1286, but also more expensive.
Silastomer 9161 is one of a number
of candidates which might ultimately
replace RD 1286, but its use has
been proposed only in WP filled shell.

Composition Silastomer 9161   100 pts/wt

Catalyst N 9162   2 pts/wt

Reports   Reference 24

Literature from:

Midland Silicones Ltd
Reading Bridge House
Reading
Berks

DATA SHEET NO 7

THREAD SEALER TS 479

Description   A two-part polyurethane cement, forming
                a grey viscous fluid when freshly mixed,
                and setting to a soft rubber in about
                16 hours at 20°C.   TS 479 thus has a
                longer pot life than either RD 1286 or
                Silastomer 9161.   Like the latter, it is
                a candidate to replace RD 1286;   it is
                likely to be cheaper than silastomers,
                but dearer than RD 1286.

Composition   Part A   :   50 pts/wt

                Part B   :   50 pts/wt

Reports   Reference 24

                Literature from:

                Alfred Jeffery & Co
                Marshgate Lane
                Stratford
                London E15

DATA SHEET NO 8

SILASTOSEAL E

Description   Silastoseal E is a white, free
                   flowing, one-part silicone rubber
                   sealant which sets at room tempera-
                   ture to a soft rubber. It is ready
                   to use and cures on contact with
                   atmospheric moisture. Preliminary
                   trials have shown it to be a good
                   candidate to replace RD 1286, and
                   it has the advantage that it requires
                   no mixing. It is, however, rather
                   expensive.

Composition   Silicone rubber

Reports   Technical data sheet K51, from:

                   Midland Silicones Ltd
                   Reading Bridge House
                   Reading
                   Berks

DATA SHEET NO 9

LOCTITE SEALANTS

Description   Loctite sealants comprise a family of liquid dimethacrylates (viscosity 10 - 100 poise) which polymerise to plastic materials of various degrees of flexibility in joints between mating metal surfaces. This process occurs chemically when the liquid is in contact with metal and air is excluded. By using a primer, materials other than metals (eg ceramics, glass and some plastics) may be joined. Loctites are very attractive as thread sealants and withstand thermal cycling when the components of the joint have similar coefficients of thermal expansion. Unfortunately, however, joints between components having different coefficients leak on thermal cycling.

Composition   Dimethacrylates

Reports   References 13, 15, 21, 24

Literature from:

Douglas Kane (Sealants) Ltd
Swallowfields
Welwyn Garden City
Herts

DATA SHEET NO 9

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Composition   Dimethacrylates

Reports   References 13, 15, 21, 24

Literature from:

Douglas Kane (Sealants) Ltd
Swallowfields
Welwyn Garden City
Herts

5   ACKNOWLEDGEMENTS

6   BIBLIOGRAPHY AND ABSTRACTS

1   Bryant R W, Dukes W A,   A Manual of Sealing
      Gooding J   Compositions for Ammu-
                                   nition (Incorporating
                                   ERDE Report No 27/R/55)
                                   January 1956.

The many factors influencing the choice of suitable
sealing methods for ammunition and allied stores
are summarised. The importance of adequate water-
proofing is emphasised, in view of the widely varying
atmospheric and other conditions to which stores in
Service are liable to be subjected.

The types of joint normally used are considered, and
the methods of applying sealing compositions to them
are discussed.

Details of all current compositions are given on
individual data sheets; obsolescent and obsolete
compositions are described in rather less detail.

2   Webb B L   Sealing Compositions: Their
                                    Application to Armament
                                    Design: Pt 1: Ammunition
                                    ADE Technical Information
                                    Sheet No TI 5, May 1954.

This information sheet deals with various design
aspects of ammunition sealing, including types of
leakage, climatic conditions and application of
sealing compositions to joints. Typical examples
of sealed joints are shown and the sealing
compositions used in ADE joint designs are
tabulated.

BIBLIOGRAPHY AND ABSTRACTS (Contd)

3   Dukes W A   Improved Luting Compositions:
                            Part 4: The Development and
                            Trials of RD 1287, a Luting with
                            Improved Low Temperature
                            Performance
                            ERDE Report No 15/R/55 July 1955.

A new luting, RD 1287, has been developed with improved
low temperature performance and unimpaired high
temperature performance, when compared with RD 1284
(Luting Mk 8).

Luting Mk 8 was introduced as satisfactory over the
"Normal" Service temperature range; subsequently
however a particular requirement was published for
dynamic functioning at the operating minimum of the
"Universal" temperature range [ie 40°F (22°C) lower] .
RD 1287 fulfils this requirement and is satisfactory
in typical Service applications throughout the
"Universal" range [-80°F to +160°F (-62°C to +71°C)].

RD 1287 has a water vapour transmission rate similar
to that of other Service lutings, excepting Luting Mk 8,
whose rate is exceptionally low. Its water-repellency
is greater than, and its water-resistance is equal to,
that of Luting Mk 8. It is less reactive towards
brass than any other Service luting. Its thermal
stability, both physical and chemical, is similar to
that of Luting Mk 8, and is satisfactory. RD 1287
is compatible with representative high explosives and
propellants, although it causes a slight reduction
in the life of propellant N under moist conditions.

40

BIBLIOGRAPHY AND ABSTRACTS (Contd)

4   Dukes W A   Cements for Sealing Ammunition:
                              Pt 1: RD 1286, an Improved
                              Solvent-Free Cement Based on
                              Cashew Nut-Shell Liquid
                              DMXRD Report No SEAL/56/1
                              August 1956

RD 1286, a new cement which has been developed, is
based on cashew nut-shell liquid. It is compatible
with representative high explosives (except amatol),
with single- and double-base propellants, with
representative plastic propellants and with gunpowder.

By comparison with Service magnesium oleate cements,
such as RD 1241B and RD 1248, RD 1286 has improved
characteristics including suitability over the
Service temperature range, lower contraction,
greater flexibility, higher strength, and more
convenient pot life and setting time. It is
easier to mix correctly and to apply and it is
also a better thread sealer.

BIBLIOGRAPHY AND ABSTRACTS (Contd)

5   Dukes W A   Improved Luting Compositions:
                          Pt 5: RD 1284A, a Sealing
                          Composition for Filling
                          Crevices
                          DMXRD Report No SEAL/56/2
                          August 1956

A new stiff plastic luting, Sealing Composition
RD 1284A, has been developed. It is analogous to
RD 1284 (Luting Mk 8), and consists of a dispersion
of a high melting point synthetic wax in poly-
isobutene of low molecular weight (provisional
British patent specification No 24973/52).

RD 1284A is superior to the stiff Service lutings
(Lutings Mks 4 and 6, and Luting, Optical No 1 Mk 1)
in that its consistency is much less affected by
changes in temperature. In contrast with the
Service lutings, it should perform satisfactorily
throughout the "Normal" Service temperature range,
although in some applications it may become too
brittle near the low limit of this range. The water-
repellancy, water-resistance and water vapour
transmission rate of RD 1284A are better than those
of Luting Mk 6 and Luting, Optical No 1 Mk 1 and
slightly worse than those of Luting Mk 4.

By analogy with RD 1284, RD 1284A should be satis-
factorily compatible with common Service metals, with
other typical sealing compositions and varnishes,
and with explosives. Presstite Elastic Compound No 155,
a proprietary composition manufactured in USA, has
also been examined. It has many desirable properties.

BIBLIOGRAPHY AND ABSTRACTS (Contd)

6   Bryant R W, Dukes W A   Cements for Sealing
                                  Ammunition: Pt 2:
                                  The Inadequacy of Cements
                                  Containing Solvent in
                                  Threaded Joints
                                  DMXRD Report No SEAL/56/3
                                  October 1956

The properties which directly affect the functional
efficiency of a cement for sealing threaded joints
in ammunition are considered. The most important
physical requirements are (a) rapidity in setting,
(b) high ultimate strength and (c) efficient
sealing (waterproofing).

With minor exceptions, all the cements tested which
contain solvent are unsatisfactory, in that they
set very slowly, have low ultimate strengths and
fail to waterproof a standard metallic threaded
joint. In contrast chemically setting cements
are shown to set very much more quickly, to be
generally stronger, and to be considerably more
efficient in sealing.

Cements containing solvents should therefore not
be used to seal or rapidly secure metallic
threaded joints.

7   Bryant R W, Dukes W A   The Effect of Solvents
                                    on Cements RD 1241B
                                    and RD 1286
                                    DMXRD Tech Note No
                                    SEAL/57/1
                                    November 1957

Samples of cements RD 1241B and RD 1286, after various
periods and temperatures of cure, were immersed in
various solvents at 25°C and the effects noted. The
resistance of RD 1241B to all the solvents tested
(except ethylene glycol) was poor. RD 1286 was
unaffected by liquids of high solubility parameter
(eg, water), and was superior to RD 1241B in its
resistance to solvents of low solubility parameter.
RD 1286 was rapidly disintegrated by those solvents
with solubility parameters about 9, ie trichlor-
ethylene, carbon tetrachloride, acetone and coal tar
naphtha.

8   Bryant R W, Dukes W A   The Sealing of Threaded
                             Joints: Pt 1: Sealing
                             Compositions and Joint
                             Design
                             DMXRD Report No SEAL/57/3
                             January 1958

The most important single factor in the sealing of
threaded joints is the quality of the sealing
composition. Cements which dry merely by evapora-
tion of solvent are greatly inferior to solvent-free
cements and to lutings. RD 1151B is the least, and
RD 1286 the most, satisfactory cement tested.

The next most important factor is the combination
of joint design with mode of application of the
sealing composition. Application to both threads
is preferable, if it is permissible to force
composition into the assembly. Sealing is also
improved by screwing on to either (a) an external
shoulder if composition is applied to the male
threads, or (b) an internal shoulder if composition
is applied to the female threads. A joint not
screwed on to a shoulder is relatively difficult to
seal.

The metal and dimensions of the joints, and even
incorrect application of the sealing composition,
are individually of minor importance.

9   Bryant R W, Dukes W A   Hot storage Trials of
                                     the Ingredients of
                                     Thread-Sealing Cements,
                                     RD 1241B, RD 1248 and
                                     RD 1286
                                     DMXRD Report No SEAL/57/4
                                     February 1958

Variations in properties during storage at elevated
temperatures of the ingredients of three current
thread-sealing cements have been determined.

The liquid ingredient of each cement becomes more
reactive on storage, causing a reduction in the pot
life (or period of use) of the cement. RD 1241B is
inferior to the other cements in this respect, as
storage rapidly results in an inconveniently short
pot life. The originally very long pot life of RD 1248
is greatly reduced, but never becomes inconveniently
short. Except on storage at 75°C, the useful lives of
the liquid ingredients of RD 1286 and RD 1248 are
similar. The solid ingredient of RD 1286 however
becomes less reactive on storage.

No serious change is likely to occur in the pot life
or strength in threaded joints of RD 1286 after prolonged
storage of the ingredients at temperatures up to
40°C (104°F).

10   Bryant R W, Dukes W A   The Strength of
                              Threaded Joints: Pt 1:
                              Resistance to Mechanical
                              Shock
                              DMXRD Report No SEAL/58/1
                              May 1958

The strength (that is, the failing torque) of a
cemented threaded joint is the sum of the tightening
torque and the contribution of the cement.

The resistance of steel threaded joints [assembly
weighing 2 lb (0.91 kg); thread 1 inch (25.4 mm) in
diameter] to a single axial impact when dropped 4 ft
6 in (1.37 m) on to concrete has been investigated.
For joints screwed on to the external shoulder:
(i) a tightening torque of 30 ft lb (40 J) is
necessary to resist one impact if there is no sealing
composition in the joint, (ii) a tightening torque
of 10 ft lb (14 J) is necessary if the joint is luted
and (iii) less than 10 ft lb (perhaps nil) is necessary
if the joint is cemented. Similar, but perhaps
higher, tightening torques are required if the joint
is screwed on to the internal shoulder.

11   Bryant R W, Dukes W A   The Sealing of Threaded
                                   Joints: Pt 2: Thermal
                                   Cycling and Mechanical
                                   Shock
                                   DMXRD Report No SEAL/58/2
                                   July 1958

The effect of mechanical stresses caused either by
cyclic changes of temperature, or by impact, on the
sealing of various threaded joints has been determined.
Thermal cycling does not affect the sealing of joints
unless the components are made of dissimilar metals.
The most important single factor is the joint design
(external, internal, or no shoulder), coupled with
mode of application of sealing composition. The next
most important factor is the quality of the sealing
composition. RD 1286 is the best cement and RD 1284
(Luting Mk 8) the best luting, examined. There is no
significant difference between the performance of
joints made of different bimetallic combinations. A
single axial impact caused by dropping steel threaded
assemblies "end-on" through 4 ft 6 in (1.37 m) to
concrete has little effect on the sealing.

12   Dukes W A   Optical Lutings
                             DMXRD Tech Note No SEAL/58/3
                             February 1959

Some physical properties of RD 1284A, a stiff luting
which has been introduced recently, have been
compared with those of optical lutings (ie, Luting,
Optical No 1 Mk 1 and Luting, Wax Renax) and of a
few similar proprietary compositions.

The consistency of RD 1284A was much the least affected
by changes in temperature: it softened least at
75°C and stiffened least at -30°C.

RD 1284A was not inferior to the Service material,
Luting Optical No 1 Mk 1, in adhesion to glass and
metals, neither did it smear glass more.

A Service trial of RD 1284A as an optical luting is
suggested.

13   Bryant R W, Dukes W A   The Bonding of Threaded
                              Joints: Pt 1:   Loctite
                              Cements
                              DMXRD Report No ADH/58/1
                              February 1959

Three grades (D, C and E) of Loctite thread-bonding
cement have been examined. The strengths (that is,
the failing torques) of steel threaded joints of
various dimensions cemented with Loctite have been
measured. It has been shown that the failing torque M
(in ft lb) may be calculated from the following
equations:

for Loctite grade D, $M = 130 \, L.D_E^2$

for Loctite grade C, $M = 40 \, L.D_E^2$

for Loctite grade E, $M = 30 \, L.D_E^2$

where L is the length of engagement (or nut thickness)
and D_E is the effective diameter of the thread, both
in inches.

A variation of ± 30 per cent is usual in the strength
of replicates even when the joint is completely
filled with cement.

14   Bryant R W, Dukes W A   Nomogram for Deriving
                                Failing Torques of
                                Steel Threaded Joints
                                Cemented with RD 1286
                                DMXRD Tech Memo No
                                TM/59/1
                                October 1959

RD 1286 is a cement, based on cashew nut-shell
polymer, which has been found effective for
sealing and bonding screw-threaded joints. It is
applied as a fluid which sets to a rubbery gel: this
subsequently strengthens to a degree governed by
the temperature and period of storage. Consequently,
threaded joints cemented with RD 1286 have strengths
(or failing torques) dependent not only on the
geometry of the joints but also on their history.
The nomogram relates the mean failing torques of
steel threaded joints to these parameters.

It covers periods of storage up to 10 years at
temperatures ranging from 15 to 75°C, and components
having nominal thread diameters from $\frac{1}{8}$ in to 16 in,
with lengths of engagement from $\frac{1}{8}$ in to 8 in.

A variation in strength of ± 30 per cent of the mean
is normal for joints completely filled with cement.

15   Bryant R W   The Sealing of Threaded
                                    Joints: Pt 3: Surface
                                    Catalysed Compositions
                                    DMXRD Report No SEAL/59/1
                                    November 1959

The sealing efficiency of surface-catalysed composi-
tions has been examined in brass, aluminium and
steel threaded joints.

These compositions differ from conventional chemically-
setting cements because their setting rate depends on
the metal of the adherends and setting is inhibited
at air interfaces. They are less efficient than
conventional chemically-setting cements as thread-
sealers and this is probably because they are much
less viscous. Grade AV, the most viscous tested,
seals the best.

Some of the conclusions reached in Part 1 of this
series of reports, about sealing with conventional
cements, are not valid for these recently introduced
compositions. For example, brass assemblies are
easier to seal with surface-catalysed compositions
than are aluminium, which are in turn easier to
seal than steel. Also, a joint is more easily sealed
if so disposed that a fillet of composition open to
the air can act as a reservoir to fill holes in the
joint.

16   Dove E E   Improved Waterproofing of
                                  Fuzes
                                  Report ROF/DOF/AMM/No 35
                                  February 1960

This report gives a survey of the investigations
and development of new methods of hermetic sealing
for fuzes. No attempt has been made to develop
chemical sealing methods such as lutings, cements
etc, since a great deal of work has been carried
out by Establishments specialising in this type
of work. The investigations as such have
therefore been confined to mechanical type
sealing. The following processes have been
considered:

  (i)   Cold welding - considered unsatisfactory
        for fuze assembly.

  (ii) Application of Seals in Latex form -
        satisfactory sealing obtained by this
        method.

 (iii) Swaged Joints - a satisfactory method of
        assembly giving good seals together with
        economy of machining and assembly time.

  (iv) Metal Injection - satisfactory seals can be
        obtained but the use of this process
        probably could not be justified on con-
        ventional fuze work. Swaged joints with
        conventional 0-seals or with moulded
        on seals are recommended.

17   Bryant R W, Dukes W A   The Kinetics of Cross-
                            linking of a Polyphenol/
                            Formaldehyde Rubber
                            DMXRD Report No RU/59/2
                            April 1960

The chemical kinetics of the reaction between
formaldehyde and a polyphenol derived from cashew
nut-shell liquid have been investigated by measuring
gelation times and by measuring the Young's modulus
of the rubbery product at intervals.

The reaction leading to gelation is first-order with
respect to formaldehyde, and has an activation energy
of 20 kcal/mole (84 kJ/mole). The post-gelation
cure is also first-order with an activation energy
of 23 kcal/mole (96 kJ/mole). On prolonged heating
the rubber continues to stiffen, up to a maximum
modulus. This "overcure" reaction is also first-
order, and very much slower at elevated temperatures
than the formaldehyde crosslinking reaction. The
specific reaction rates, k_1 for the curing reaction,
and k_2 for the over-cure reaction, are given by the
following Arrhenius equations:

$$k_1 = 5 \times 10^9 \quad \exp (-23 \times 10^3/RT) \quad s^{-1}$$

$$k_2 = 2 \times 10^{-2} \quad \exp (-8 \times 10^3/RT) \quad s^{-1}$$

18   Bryant R W, Dukes W A   The Physical Properties
                                   of a Polyphenol/Formal-
                                   dehyde Rubber at Various
                                   Degrees of Crosslinking
                                   DMXRD Report No RU/59/3
                                   May 1960

"Cellobond H 8160", a polyphenol derived from
cashew nut-shell liquid, when crosslinked with
paraformaldehyde yields a rubber-like material of
which the physical changes during polymerisation
can be followed more conveniently than in ordinary
rubber vulcanizates. Immediately after gelation
it shows Hookean behaviour in simple extension.
As further crosslinking occurs the stress-strain
curves at first conform with the statistical
theory of rubber elasticity; then the
phenomenological (Mooney-Rivlin) theory is
apparently obeyed. Finally the relation again
appears Hookean. The modulus increases through the
range 1 to 10^5 lb/in^2 (0.07 to 6900 bars). The
particular composition containing six parts by
weight of paraformaldehyde per hundred of resin
(cement RD 1286) is probably fully cured when there
is one crosslink per phenolic nucleus. Its change in
tensile strength during cure conforms with the theory
of F Bueche. The tensile modulus, strain energy and
elongation at break, and the density, all show
inflexions corresponding to complete cure with
methylene links. The solubility parameter does not
very appreciably with the degree of polymerisation;
the experimental value agrees with that calculated
from molar attraction constants.

19   Bryant R W, Dukes W A   Some Sealing Materials
                                for Threaded Joints
                                Paper B3, the 1st B.H.R.A.
                                International Conference
                                on Fluid Sealing
                                April 1961

The development of special sealing compositions, both
lutings and cements, for parallel threaded joints is
summarised, and their performance is described. The
most important single factor in the sealing of
threaded joints is the quality of the composition.
Desirable qualities are discussed. Cements which dry
merely by evaporation of solvent are greatly inferior
to solvent-free cements and to lutings.

20   Bryant R W, Dukes W A   The Bonding of Threaded
                                Joints: Pt: 5 The
                                Failing Torque Relative
                                to the Shear Strength
                                of the Corresponding
                                Planer Joint
                                ERDE Report No 19/R/61
                                November 1961

Previous measurements of the failing torques of
bonded threaded joints have been converted into
shear strengths, assuming that there are no stress
concentrations and that the cement over the whole
of the threaded surface is sheared. The strengths
so obtained have been compared with the shear
strengths of standard planar joints of the same
materials. It has been shown to be necessary to
take into account the glue-line thickness.

There is no significant difference between shear
strengths measured in threaded or planar steel
joints of the same glue-line thickness, whether
the cement is brittle or rubberlike, strong or
weak.

This is not true, however, if the cement is
capable of viscous flow. In this case, and
perhaps generally if the adherends are light alloys
or plastics, threaded joints appear a few times
weaker than comparable planar joints.

21   Bryant R W, Dukes W A,   The Increase in Strength
      Long Mrs J V   with Time of Metal-
                                   Metal Joints Bonded by
                                   Surface-Catalysed
                                   Compositions
                                   ERDE Tech Memo No 19/M/61
                                   November 1961

The rates of setting of various commercially available
surface-catalysed adhesives, based either on
dimethacrylates or on a cyano-acrylate, have been
investigated. The shear strengths of planar joints
of brass, steel and aluminium alloy were measured
after various periods of cure at room temperature.
The rates of accretion of strength are shown graphi-
cally. Of the substrates, the aluminium alloy was
the least efficacious as a catalyst. Brass always
gave the least period of inhibition of solidification.
Similar ultimate strengths were found on brass and
steel, and lower strengths on aluminium alloy.

In general, the lower the ultimate strength, the
longer was the time taken to attain it. The cyano-
acrylate composition was by far the strongest and
quickest setting material tested.

22   Dukes W A, Long Mrs J V   The Sealing of Threaded
                                 Joints: Pt 4:
                                 Polytetrafluorethylene
                                 Tapes and Cord
                                 ERDE Tech Memo No 16/M/62
                                 January 1963

The sealing efficiency of commercial grades of PTFE
tape and cord has been examined in brass, aluminium
and steel parallel-threaded joints. These materials
can only be applied to the male component. The
weakest and softest grade was the most satisfactory,
but if it was not carefully wrapped over the whole
thread before assembly it was less successful. The
loss of efficiency due to application over only a
fraction of the thread was less for material in
the form of cord than in the form of tape. However
it is comparatively expensive, laborious and time-
consuming to wrap a yard of cord round the complete
thread of a joint, although the process is cleaner
than applying luting. In general, the cord was
more efficient than the lutings, which were more
efficient than the best PTFE tape.

Between heterometallic components, neither the PTFE
materials nor the lutings provided seals which
could withstand thermal cycling.

Neither the metal of the joint nor the degree of
compression of the enclosed air at assembly has
any important effect on the ease of sealing
threaded joints with PTFE.

59

23 Bryant R W, Dukes W A,   Commercial Lutings
    Long Mrs J V   ERDE Memo No 10/M/63
                             January 1964

Twenty firms specialising in sealing compounds were
sent a performance specification for soft lutings
(with which the Service compositions, Lutings Mk 8
and Mk 9 comply), and were asked to submit samples
for evaluation. Eight materials were submitted,
but only one, Hylomar SQ 32/S is likely to find
Service applications. It is superior to the existing
lutings in its resistance to petroleum products and
is more extensible. It is as good as the existing
lutings in its resistance to flow at 75°C (167°F)
and in its compatibility with explosives. It is
intermediate between the two Service compositions
in respect of its embrittlement temperature and
in its sealing efficiency in screw threads.
However, it is inferior in its consistency at low
temperatures, heat stability in contact with brass,
and water resistance. It could not be recommended
as an alternative to the existing Service Lutings
Mk 8 and Mk 9 for general use, but it has poten-
tially valuable properties which may find use in
specialised applications.

24   Bryant R W, Dukes W A,   The Sealing of Threaded
      Long Mrs J V   Joints: Pt 5: A Review
                                   of Commercial Sealants
                                   ERDE Report No 10/R/66
                                   August 1966

Commercial lutings and thin polytetrafluorethylene
(PTFE) tapes and cord have been assessed as
sealants for parallel-threaded joints. One luting
is comparable with the Service materials and may
find specialised uses. The relative inefficiency
of PTFE tapes will often outweigh the advantage
of cleanliness, unless resistance to extreme
temperatures and to a variety of solvents is
required.

Twenty-four commercial cements, including poly-
sulphides, polyurethanes, epoxides, silicones,
surface-catalysed compositions and compounds
hardened by atmospheric moisture, have been
assessed as thread sealants. Several were
superior to the Service material in a stringent
thermal-cycling trial.

Theoretical analysis of the imposed strain has led
to an understanding of the necessary magnitudes of
the adhesive and cohesive strength and the
flexibility of a sealing cement. These properties
can now be specified as a function of the materials
and dimensions of the joint and of the tempera-
ture range to be withstood.

OUTLINE OF A PERFORMANCE SPECIFICATION FOR
SOFT LUTINGS FOR AMMUNITION

1	Scope	This specification relates to soft lutings for ammunition, particularly for waterproofing and sealing threaded joints. The luting is intended for applications where a high degree of compatibility with explosives is required but its compatibility with all explosives in all environments has not been established. Advice on compatibility requirements in particular applications should be sought from ERDE or other competent authority. It may be compounded from any materials provided the product complies with the requirements of this specification.
2	Description	The luting shall be an homogenous mass, free from foreign matter and visible impurities, having the consistency of a stiff grease. It must wet, and adhere strongly to, metal surfaces. It may be required to be coloured by means of an approved pigment or dyestuff.
3	Compatibility with explosives	a The luting must be type-tested for compatibility with explosives,

b   Samples may be taken at any time to check that compatibility with explosives remains unchanged.

c   The manufacturer must disclose in confidence to the Inspecting Authority the composition and method of preparation of the luting and must undertake to notify the Inspector in advance of any proposal to change either composition or method of preparation.

4	Behaviour on heating (flow test)	When tested by the method described in Annex 1, the luting shall show no appreciable flow, neither shall there be any sign of syneresis nor separation of any of the ingredients.
5	Low Temperature penetration	When tested as described in Annex 2, no value of the penetration shall be less than 30 units.
6	High Temperature penetration	When tested as described in Annex 3, no value of the penetration shall exceed 250 units.
7	Elongation	When tested as described in Annex 4, the mean elongation shall be not less than 60 mm.

8	Non-corrosive properties	The luting shall not cause corrosion of copper, brass, aluminium or mild steel surfaces when tested as described in Appendix A of BS 3245 : 1960.
9	Water resistance	When tested by the method described in Annex 5, the luting shall show good water repellency, shall not change appreciably in appearance, and shall show no evidence of penetration of water from the exposed edges of the luting.
10	Heat stability	When tested by the method described in Annex 6, the luting shall not change appreciably in consistency nor shall it be discoloured or show any evidence of cracking or separation of any ingredient.
11	Ash content	The ash content, determined by the method described in IP 4/61, shall not exceed 0.1 per cent.
12	Lead content	The luting shall not contain lead or lead compounds together exceeding 0.03 per cent by weight, calculated as metallic lead.

METHOD FOR DETERMINATION OF BEHAVIOUR
ON HEATING

Use a metal container of rectangular section
with the following internal dimensions:

Base ....   25 mm x 25 mm

4 sides .....   25 mm x 12.5 mm

The nature of the metal from which the container is
made is not critical.

Fill the container at 75°C with the material at the
same temperature. Level off the surface of the
material with a warm knife.

Maintain the assembly on one side, with the exposed
surface of the material vertical, at 75°C for
24 hours.

METHOD FOR DETERMINATION OF LOW
TEMPERATURE PENETRATION

Determine the low temperature penetration of the
material by the standard method of the Institute of
Petroleum serial designation 49/63, but ignore
references to a water bath and a transfer dish, and
use the following method for preparation of the sample
and procedure.

PREPARTION OF SAMPLE AND PROCEDURE

Fill the specified container at room temperature with
the material to be tested taking care to avoid entrap-
ment of air. Smooth flat the surface of the material,
using a knife at room temperature.

Cool the filled container to -45°C and maintain at
that temperature for two or more hours, then quickly
transfer to the stand on the penetration machine and
determine the penetration within 30 seconds. Make
three determinations, cooling the sample container
for at least two hours at -45°C immediately prior to
each determination, or alternatively use three
separate filled containers. Except where specified
otherwise, follow all details of the test method as
laid down in IP 49/63.

METHOD FOR DETERMINATION OF HIGH TEMPERATURE PENETRATION

Determine the high temperature penetration of the material by the standard method IP 50/62 but ignore reference to a grease worker and a constant-temperature bath, and use the following method for preparation of the sample and procedure.

PREPARATION OF SAMPLE AND PROCEDURE

Use a container as specified in IP 49/63 for the determination of low temperature penetrations exceeding 225 units. Fill it with the material to be tested in the manner described in Annex 2.

Heat the filled container to 75°C and maintain at that temperature for two or more hours, then quickly transfer to the stand on the penetration machine and determine the penetration within 30 seconds. Without smoothing the surface make two more determinations, heating the sample container for at least 2 hours at 75°C immediately prior to each determination. Alternatively use three separate filled containers. Do not maintain the sample at 75°C for more than a total period of 24 hours. Except where specified otherwise, follow all details of the test method laid down in IP 50/62 using the procedure for 'Unworked Penetration'.

METHOD FOR DETERMINATION OF ELONGATION

Press the material to be tested into two brass tubes
51 mm (2 in) long and 19 mm (¾ in) in internal
diameter, co-axially butt-jointed together to form a
single tube. Take care to avoid inclusion of air
into the cylindrical test specimen. Maintain the
assembly in an incubator for 6 hours at 25°C. Pull
the brass tubes vertically apart along the axis at
500 mm/minute (20 in/minute) and observe the extending
thread of material. Note the separation of the tubes
at the moment of rupture and report as the elongation
of the material.

Prepare three separate test specimens from each sample
and take the mean of three determinations.

METHOD FOR DETERMINATION OF WATER RESISTANCE

Degrease with ethyl methyl ketone two flat glass microscope slides each 25 x 75 mm. Stick these together at right angles in the form of a cross by means of a film of the luting about 1 mm thick and 25 mm square, removing any excess of luting extruded during the preparation. Immerse the assembly in tap water at 60°C and maintain these conditions for 4 days. Then allow the assembly to cool to room temperature without removing it from the water. When at room temperature, remove the assembly and shake off excess water. Inspect the free surface of luting for water repellancy and for signs of degradation (eg whitening) or other changes in appearance. Examine the luting/ glass interface through the glass for any evidence of water penetration.

DETERMINATION OF HEAT STABILITY

Prepare clean glass and brass surfaces as follows:

a   Glass: Wash well with hot water containing a
               detergent, rinse thoroughly under
               running tap water and allow to drain
               and dry at room temperature.

b   Brass: Abrade the surface uniformly with 0
               grade emery cloth, wipe and degrease
               with ethyl methyl ketone.

At room temperature, spread the luting evenly to
a depth of approximately 1 mm on to glass and brass
surfaces prepared as above, and place the coated
specimens in an oven at 75°C. Maintain these
conditions for 3 months, then cool to room tempera-
ture. Compare the coating of luting with a similar,
freshly prepared, specimen for discolouration or
any change in consistency. Inspect the surface for
evidence of cracking or separation of any ingredient.

OUTLINES OF A PERFORMANCE SPECIFICATION
FOR GENERAL-PURPOSE AMMUNITION CEMENTS

1	Scope	This specification relates to general-purpose cements for ammunition. These materials are applied as fluids and subsequently set to become rubbers in the joint. They are intended for applications where a high degree of compatibility with explosives is required, combined with resistance to thermal shock. Their compatibility with all explosives in all environments has not been established. Advice on compatibility requirements in particular applications should be sought from ERDE or other competent authority.
		They may consist of any materials which will comply with the requirements of this specification.
2	Description	The mixed cement shall be free from lumps and shall have the wetting properties necessary for adhesion to metal surfaces.
3	Consistency and Pot-life	The freshly prepared cement shall have a viscosity not less than $1\,N\,s/m^2$ (10 poise) at $25^{o}C$, and, when maintained at this temperature for one hour, the viscosity shall not be greater than $250\,N\,s/m^2$ (2500 poise).

71

4   Gelation Time   The gelation time at 20°C, measured with a Techne Gelation Timer (Techne (Cambridge) Ltd) shall not exceed 24 hours.

5   Contraction on setting   The contraction on setting shall not exceed 4 per cent by volume.

6   Non-corrosive properties   The composition shall not cause corrosion of copper, brass, aluminium or mild steel surfaces when tested as described in Appendix A of BS 3245 : 1960.

7   Resistance to flow at elevated temperatures   Cast a 10 mm cube of the material and cure it for 3 days at 100°C. Place the unsupported cube in a suitable air oven at 75°C. The cube shall retain its shape under these conditions for 24 hours.

8   Compatibility with explosives   a   The cement must be type-tested for compatibility with explosives.

     b   Samples may be taken at any time to check that compatibility with explosives remains unchanged.

     c   The manufacturer must disclose in confidence to the Inspecting Authority the composition of the cement and must undertake to notify the Inspector in advance of any proposed change in composition.

9	Preparation of sheet material	Cast a uniform sheet of cement 1 to 3 mm thick and cure for 3 days at 100°C. This sheet is used for the tests in clauses 10, 11 and 12 below.
10	Stiffness at low temperatures	Measure the apparent rigidity modulus of the fully cured sheet material (clause 9 above) at -45°C by the method described in ASTM D1043/61T. The apparent rigidity modulus at -45°C shall be not greater than 3100 bars (45 000 psi).
11	Water absorption	Weigh a portion of the cured cement (clause 9 above) and wholly immerse it in distilled water at 60°C. Maintain these conditions for 4 days, then remove the sample, wipe off the excess water with filter or blotting paper and reweigh. The gain in weight, calculated as a percentage of the original weight, shall not exceed 3 per cent.
12	Strength and adhesion	The cement, cured for 3 days at 100°C, shall have a tensile cohesive strength, and adhesive shear strengths with aluminium, brass and mild steel adherends, not less than one-third its rigidity (shear) modulus, all measured at 20°C.

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Explosives Research and Development Establishment
HANDBOOK OF SEALANTS FOR AMMUNITION
R W Bryant
September 1971
75 pp, no tabs, 2 figs

The many factors influencing the choice of suitable sealing methods for
ammunition and allied stores are summarised. The importance of adequate
waterproofing is emphasised, in view of the widely varying atmospheric and
other conditions to which stores in Service are liable to be subjected.

The properties required in sealing compositions are outlined and performance
specifications for lutings and cements are proposed. Details of selected
lutings and cements are given on individual data sheets.

The types of joint normally used are considered, and the methods of
applying sealing compositions to them are discussed.

A bibliography with abstracts of 24 references is included.